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Final Report

# GEOMETRIC PROCESSOR AND MULTIVARIATE CATEGORICAL PROCESSOR MARKET ANALYSIS

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This report is the result of an IR&D task to analyze the marketability of ERIM's Geometric Processor (GP) and Multivariate Categorical Processor (MCP). Existing systems similar to the GP and MCP were identified and characterized. Potential applications were investigated and are presented. New capabilities or functions are identified that, if added to ERIM's GP or MCP, could increase their marketability.

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# Preface

This report contains the results of a marketability analysis of ERIM's Geometric Processor (GP) and Multivariate Categorical Processor (MCP). Prior to committing resources to produce commercial versions of these systems, we attempted to determine if a profitable niche exists in the application community.

This report is organized into two parts. Part I is devoted to discussing the GP while part II discusses the MCP. Both parts are subdivided into five sections. In section one, the capabilities of the processor are presented. The capabilities of similar commercially available systems are assessed and presented in section two. Section three is devoted to identifying and presenting potential application areas for the processor. Section four identifies additional capabilities that, if added to the ERIM processors, could increase its marketability. Section five concludes with an implementation plan for follow-on activity.

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# 1.0 GEOMETRIC PROCESSOR

## 1.1 Capabilities of ERIM's Geometric Processor

The Geometric Processor (GP) was designed to rectify remote sensor image distortions, to reformat the images into map projections, to register (merge) multi-source image and geographic data sets, and to change data resolution. This is accomplished by pairing desired remapping control points with control points from the original image. By using these points, a set of equations can then be formed which describe the image transformation or warp.

The GP can be programmed by a VAX host with the calculated spatial transformation equations. The transformation equations are used by the GP hardware to determine the location to which the pixel is mapped. This process is known as address generation and produces noninteger results. The GP is capable of performing up to seventh order polynomial transformations.

In order to determine the desired pixel value at noninteger locations, interpolation hardware resamples the source image. The area resampled is determined by the size of the interpolation filter or kernel. The two popular resampling procedures in current use commercially are nearest-neighbor and cubic-convolution. The GP implements these and, in addition, any other linear combination of nearby input pixels up to an array size of 16 rows by 16 columns. Four row by eight columns is usually used for the proprietary resampling method referred to as restoration.

When resampling four band data with a four-by-eight array for restoration or a similar interpixel estimation scheme, the resampling processor requires about 60$\mu$s per output pixel. The GP performance is limited by the resampling process for large local arrays, and by the mapping polynomial processor for small arrays, including the one-by-one nearest neighbor case.

### 1.1.1 Hardware Capabilites

| | |
|---|---|
| Output Rate: | Four band data with a 4 by 8 restoration kernel takes about 60$\mu$s per output pixel |
| Filter Aperture: | A filter size of up to 16 by 16 is supported. Nearest neighbor resampling uses a 1 by 1 kernel, cubic convolution uses a 4 by 4, and ERIM's proprietary restoration uses a 4 by 8 kernel. |
| Data Precision: | The GP accepts up to 8 bands of 8-bit pixels |
| Local Source Store: | The GP uses a 2-Mbyte input image memory, organized as 256 lines of 8K bytes. |
| Local Coefficient Store: | The resampling coefficient memory has a capacity of 64K words of 16-bits each. The polynomial coefficient memory has a capacity of 16 longwords of 32-bits each. |
| Transform: | Two polynomials of up to seventh order can be used. |
| Resolution: | With a 2Mbyte image memory the hardware restricts the image width to 8K bytes for a single band image. A two band image could only be 4K bytes wide. This hardware limit is referred to as a swath width. Software tiles together these swaths; thus, images of any size can be processed. |
| Supported Buses: | The GP is currently a UNIBUS device. The interface used is the DR11W, a DMA device. |

### 1.1.2 Software Support

Software is available to support the GP for a large family of geometric processing applications. The generation of the polynomial and resampling coefficients vary from one application to the next due to variations is sensor motion, satellite motion and the curvature and rotation of the earth. The coefficients are established by host software and can be readily modified to accommodate unique sensor requirements. Current geometric correction software is available for the generation of two 21-term, 5th degree polynomials as mapping functions.

A partial list of the applications that are currently supported by software generation of polynomial and resampling coefficients is given below:

- Landsat MSS scenes
- Landsat Thematic Mapper
- SPOT
- Aerial Photography
- Image to image mapping in which polynomials are derived from image control points

## 1.2 Commercially Available Systems Similar to the GP

The GP is the only hardware system designed solely to geometrically process remote sensor data. There are a number of other hardware image warping systems available but they are not designed to process large multiband images. Hardware overviews of the four image warping systems most similar to the GP are given in the next four sections.

There are a number of software systems available that perform the same functions that the GP performs in hardware. However, due to slow processing speeds, these systems can not effectively address applications requiring processing large quantities of images. In sections 1.2.5, a brief description of a software product available from MacDonald Dettwiler and Associates is given. Other software packages not described are available from GeoSpectra and STX.

### 1.2.1 Data Cube's Image Warper

Data Cube's Interpolator-MKII and Address Generator-MKII are second generation designs. The Interpolator is a general purpose interpolator capable of a 10MHz rate for a 4H by 2V kernel. If a larger interpolating filter is desired, more boards or more time is required. The interpolator hardware can generate up to 16-bit output values.

The Address Generator-MKII implements backward mapping of first, second and third order transformations. All address calculations and coefficients are carried out in IEEE 32-bit floating point format. Higher order polynomials as well as other nonlinear transformations may be performed by piecewise approximation.

**Hardware Capabilites**

| | |
|---|---|
| Output Rate: | Quadratics are evaluated at 100ns/pixel, while the cubics are evaluated at 200ns/pixel. |
| Filter Aperture: | Filter sizes from 4H by 2V to 8H by 8V are possible but require additional Interpolator boards to achieve high processing rates for the larger filters. For example, to maintain a 10MHz processing rate, for a 8H by 8V filter, 8 Interpolator boards are required. |
| Data Precision: | The data precision is 16-bits but can be increased by doubling the number of interpolators. |
| Local Source Store: | 256K bytes, dual-ported, 160 Megabyte/second superblock array |
| Local Coefficient Store: | 128K bytes of coefficient RAM |

| | |
|---|---|
| Transform: | Two polynomials of up to third order can be used. |
| Resolution: | The source and target arrays may be of any size less than 4096 by 4096. Larger arrays are handled by a tiling algorithm. This will slow down the application. |
| Supported Buses: | Interface to the VMEbus is available with a high-speed private bus called the MAXbus, to move image data between board modules. |

### 1.2.2 Gould's Image Warper

The Gould Hardware Warper is a two card addition to their IP8500 and IP8400 image processing systems. The warper performs geometric calculations first, then "neighborhood" interpolation to create the proper grey level from the "source" pixels. The interpolative processor is a 16-bit hardware multiplier coupled with a 36-bit accumulator and a cache memory.

**Hardware Capabilites**

| | |
|---|---|
| Output Rate: | A 2 by 2 bilinear warp on $512^2$ by 8 bit images can be performed at approximately 800ns/pixel. A 4 by 4 cubic convolution on the same size image is performed at approximately $2.8\mu s$/pixel. |
| Filter Aperture: | Nearest neighbor, 2 by 2 bilinear, 4 by 4 to 8 by 8 cubic convolution with 8 by 8 subpixel matrix. |
| Data Precision: | Warps images up to 32-bits deep |
| Local Source Store: | Local image processing system memory. |
| Local Coefficient Store: | Up to 4096 coefficients stored in image processing system memory |
| Transform: | First and second order warping |
| Resolution: | The source and target arrays may be of any size less than 4096 by 4096. |
| Supported Buses: | Gould developed image processing system bus |

### 1.2.3 International Imaging Systems Model 75

International Imaging System's image warping hardware is a small part of their Model 75 image processing system. The warper's address generation process can use up to second-order polynomial equations to determine the (x,y) location of a new output pixel. The warper can do pixel resampling via nearest neighbor, bilinear interpolation, or cubic convolution techniques. The warper reads input pixels directly from the system memory, and deposits the resultant output pixels back into memory.

The warper is output-driven; the warp spatial transformation must be provided to map from output space to input image space. An accuracy of 1/16th of a pixel is supported. A coefficient precision of twelve bits is maintained for 8-bits pixels and 4-bits of fractional accuracy.

**Hardware Capabilites**

| | |
|---|---|
| Output Rate: | A 512 by 512 second order warp can be processed in less then two seconds or approximately $7\mu s$/pixel. |
| Filter Aperture: | Pixel resampling via nearest neighbor, bilinear interpolation (2 by 2), or cubic convolution (4 by 4) are possible. |
| Data Precision: | 8-bit pixels |
| Local Source Store: | Pixel data is read directly from an image processing system memory card |
| Local Coefficient Store: | Twelve polynomial coefficients are locally stored. |
| Transform: | First and second order warping |
| Resolution: | The source and target arrays may be of any size less than 2048 by 2048. |
| Supported Buses: | Interface to virtually any host that provides "DR11-W" protocol |

### 1.2.4 MegaVision

MegaVision's 1024XM image processing system is a true thousand line image processing system. MegaVision implements image warping using their Pixel Data Flow Co-processor module. Their Pixel Data Flow Co-processor functions as a module for the 1024XM system. It is a programmable processor with eight general purpose registers, ALU, 16 bit multiplier, and a multibit shifter.

**Hardware Capabilites**

| | |
|---|---|
| Output Rate: | Using a 16 by 16 kernel, a second order warp can be processed at approximately 33ms/pixel. |
| Filter Aperture: | A filter size of up to 16 by 16 is supported. |
| Data Precision: | 8-bit pixels |
| Local Source Store: | Pixel data is read directly from an image processing system memory card. |
| Local Coefficient Store: | It is not clear how this is supported. |
| Transform: | First and second order warping |
| Resolution: | Image memory addressing is generated for an image space of 4096 by 4096. |
| Supported Buses: | Interfaces to DEC Q-Bus, Unibus, VMEbus, and IBM PC/AT bus are available. |

### 1.2.5 MacDonald Dettwiler and Associates Ltd.

MacDonald Dettwiler and Associates (MDA) designed a software product for geometric processing. The software package is called GICS (Geocoded Image Correction System) and operates on the Digital Equipment Corporation (DEC) VAX-11 series of computers under the VAX/VMS operating system.

GICS is a precision correction software package for processing imagery from advanced remote sensing satellites. The primary function of GICS is to remove the geometric and radiometric errors from the images and project the images onto a standard map system. The output of GICS is a high precision digital imagery product compatible with national and regional geocoded data bases.

GICS will accept Landsat TM, and MSS imagery, SPOT Multispectral Linear Array (MLA), and Panchromatic Linear Array (PLA) imagery.

GICS corrects for both radiometric and geometric errors. Radiometric correction is the process of changing pixel intensities from raw image values to radiometrically corrected values. Geometric errors are those which geometically distort the image. The GICS removes these errors by modeling the satellite orbit and motion based on telemetry data and external parameters. To produce a precision product, ground control points are used to "tie" an image pixel to a known ground truth.

## 1.3 Potential Applications

The GP is capable of performing very simple to very difficult computer intensive geometric processing and image warping. The GP could be used to perform a simple rotate operation on a single band 8-bit pixel image. On the computer intensive end the GP can be used in applications requiring the capabilities to perform seventh order geometric operations on 8-band remote sensor images.

In the next three sections, applications that could take advantage of the processing capabilities of the GP are presented. The first section will address the remote sensing applications the GP was initially designed for. Sections 1.3.2 addresses an application requiring the capabilities of the GP in conjunction with a Cyto-HSS via a VAX link. An example application requiring a real-time link between the GP and the Cyto-HSS is given in section 1.3.3.

### 1.3.1 Remote Sensor Imagery Processing

The GP presently is designed to be used solely for geometric processing of remote sensor imagery. Thus, geometric processing operations of remote sensor imagery data of any type are potential applications. This includes such applications as processing Landsat TM, and MSS imagery, SPOT Multispectral Linear Array, Panchromatic Linear Array imagery, and aerial photography imagery.

### 1.3.2 Generation of a Normalized Map Data Base

A system composed of the GP and the Cytocomputer could be used to normalize different size maps to a similar size. The current data path link between the GP and the Cytocomputer (via the VAX) is sufficient for this application. The VAX would function as a host for both systems.

Existing maps can be digitized by using a 40-40 optical scanner which is already in use here at ERIM. Prior to geometrically processing these images, the Cyto-HSS would first remove all map information not needed in the map normalization operations. This would include removing map symbols and half tone map backgrounds (shading dots). After the GP performed the desires normalizing operations, the Cyto-HSS would be used to restore the map symbols and half tone backgrounds.

The end result would be a digital data base of normalize map data that could be sold to interested parties.

### 1.3.3 Image Warping and Cyto-HSS Operations

First and second order image warping in conjunction with other general image processing operations is a completely different area that the GP is capable of handling. However, this would require a hardware link between the GP and the Cyto-HSS. A potential applications requiring a image warper and the Cyto-HSS is given in the following paragraph.

Phase II of the Eglin IDAPS program is expected to require the capabilities of a image warper to process Airborne Seeker Evaluation and Test System (ASETS) data and generate a normalized grid data base. Normalization of the image data for off axis image warpage by the scanner optics and flight path geometry will be expected. The Cyto-HSS is a defined system component for Eglin phase II. An image warper like the GP will be required as a subsystem component to perform the necessary normalization operations.

### 1.4 Desirable GP Enhancements

Three enhancements are addressed in the next three sections. The first enhancement involves linking the GP and Cytocomputer and is presented in section 1.4.1. A second enhancement for the GP is to add the capabilities to correctly portray terrain elevation. This enhancement, called orthorectification, is discussed in section 1.4.2. The third enhancement, to take advantage of the GP's processing speed by upgrading its I/O access rate, is discussed in section 1.4.3.

#### 1.4.1 GP and Cyto-HSS Connection

Presently, the GP is useful for purely remote sensing applications. By linking the GP to the Cytocomputer, applications that require both image warping and other image processing capabilities could be addressed.

A real-time link between the Cyto-HSS and the GP requires designing VMEbus and VSBbus interfaces for the GP. The GP resampling and polynomial coefficients would be loaded into GP resampling and polynomial RAM via the VMEbus during a programming mode of operation. The VSBbus interface would be used to transfer image data between the GP and the Cyto-HSS. In addition to a GP VSBbus, the ERIM built VSB and Cyto interface cards are require to complete the link.

The GP presently requires a 2Mbyte image memory data base to perform the resampling operations. This memory is organized as 256 lines of 8K pixels. An initial block of memory organized as indicated above would be moved from Cyto-HSS memory to a GP VSB 2Mbyte image memory. Vendor available VSBbus memory cards are available and could be used for storage of this portion of the image for processing by the GP.

Sending data from the Cyto-HSS to the GP is initiated by sending the first 256 lines of the image data. A new line of image data is required after a lapse of some time. The CPU could be programmed to wait and then instruct the Cyto-HSS to send a new line.

The Cyto-HSS is capable a handling multi-band image data. For example, a 4-band image could be separated into four separate images. The Cyto-HSS could also recombine the separate images into a single 4-band image for processing by the GP.

#### 1.4.2 Orthorectification

The second enhancement proposed for the GP is to add hardware capabilities to the GP to perform orthorectification. Orthorectification is a process that corrects geometric elevation errors or skews to a known correct elevation. Presently, this is not possible on the current version of the GP. ERIM has a preliminary software package that implements orthorectification operations.

Remote sensing sensors are now capable of sampling at a fine enough resolution to allow elevation detection of the terrain. Applications that require the abilities of orthorectification do exist.

Two competitors of ERIM also have software packages available that perform orthorecification and elevation extraction from stereo image pairs. STX is the first company and is selling their software for $125K. GeoSpectra is the other company and is advertising their software for $250K.

Elevation data is needed for the orthorecification software to perform the elevation correction operations. Unlike STX and GeoSpectra, ERIM presently does not have software capable of extracting elevation information from a pair of stereo images. However, for a small portion of the world elevation data can be obtained from existing topographical maps.

The additional hardware needed to add orthorectification capabilities to the GP is listed below:

- A $4^{th}$ memory is needed to store the length of one output line (8Kbytes)
- Two adders are needed to modify the address generator
- Small amount of additional control logic

### 1.4.3 Increase the GP's I/O Speed

An off-the-shelf array processor board set could duplicate the current processing rates of the GP as it exists in the present design. This is due to the slow I/O access rates of the hard disk and Unibus configuration. The hardware processing capabilities of the GP are not fully exercised at this point. The geometric processing hardware processes image data faster than image data can be sent to it from the hard disk.

Given an application requiring faster processing rates, the present design could be enhanced by adding faster memory accessing capabilities and data transfer rates.

## 1.5 Follow-on Activity

The GP is an ERIM product which may have a great deal of commercial value. In this paper we presented the GP and other image warpers capable of goemetric processing. The GP was identified as the only hardware capable of geometrically processing multiband imagery data. Hardware systems capable of the same multispectral geometric processing as the GP were not found.

The four commercial image warpers introduced are only capable of processing single band images. The GP is capable of processing up to eight bands with 8-bit per band of data. Satellite imagery is multispectral and therefore multiband. The only suitable hardware available to process satellite imagery is the GP.

However, geometric processing software is available and is marketed by MacDonald Dettwiler, STX, and GeoSpectra. We do not know how well the geometric processing software is selling. STX has their software priced at $125K while GeoSpectra's software is priced at $250K. It is important to note that in applications where fast processing is a necessity, the GP is presently the only solution.

Potential customers need to be identified and introduced to ERIM's geometric processing capabilities. Customers interested in orthorectification capabilities should be introduced to our current orthorectification software package. In addition, for processing large quantities of imagery we could propose purchase of an ERIM GP with orthorectification hardware capabilities.

It was indicated in section 1.4.1 that the GP could be linked to the Cyto-HSS. By implementing such a link the number of applications that the GP could address could be increased. Given the GP's processing capabilities in the remote sensing fields, we feel that with an increased marketing effort the GP could be profitable for ERIM if left solely as a geometric processor.

Adding image warping capabilities to the Cyto-HSS could be inexpensively implemented using Data Cube's two board set. Data Cube's warper is capable of processing up to $3^{rd}$ order degree polynomials. Most applications requiring a Cyto-HSS and an image warper do not need image warping capabilities beyond a $3^{rd}$ order warp. Data Cube's present VMEbus base design, MAXbus interboard communication bus, and our Cyto interface board are the tools needed to allow simple integration of a warping processor.

# 2.0 MULTIVARIATE CATEGORICAL PROCESSOR

## 2.1 Capabilities of ERIM's Multivariate Categorical Processor

The multivariate categorical processor (MCP) is an advanced spectral pattern recognition device, designed to provide speed and accuracy superior to the classical maximum likelihood algorithm. The MCP extracts land cover/land use features from satellite and aircraft data sources, using the transform coefficients that result from the investigator's ground truth training phase. It implements the repetitive computations required to process (classify) each pixel of input radiometric data according to predefined variables (or bands) and can classify up to 256 groups, providing an 8-bit output classification code. The pixel and line image data lengths are unlimited.

In the classical maximum likelihood decision, used in most multi-spectral processing, a new measurement, X, is compared to each established group. For each group, a likelihood proportional to the probability density at point X of the various group distributions is computed. The group with the greatest density at point X is selected. In multivariate categorical processing, the decision is based on the same likelihood of pixel X belonging to each group, but in a modified maximum likelihood transformed coordinate system. The result of this transformation is that, as channels of data are added to an MCP analysis, the accuracy of the results increases with the added data, which does not happen with the classical algorithm. Because of this added processing power, the MCP is able to process merged Landsat scenes, full aircraft scanner data with the thermal channel, data from the Landsat Thematic Mapper, and SPOT data. The MCP algorithm also has a speed advantage approaching four to one over the classical algorithm.

The MCP has the additional capability of changing modes (under software control) to generate the 16-bit intermediate products (or spectral features) for each pixel instead of classifying each one.

### 2.1.1 Hardware Capabilites

**Performance:**

1. Classification rate of 18$\mu$s per pixel for a four-band, eight-group problem.
2. Handles up to 16 input variables (spectral dimensions)
3. Handles up to 256 groups
4. Intermediate product generation of 16-bit precision, four to the right of the decimal point.
5. Eight-bit output for classification
6. Unlimited pixel and line image data lengths
7. 32K transform coefficient memory
8. DEC Unibus device, using a DR11C interface

**Algorithm:**

$$S_{IL} = C_{IL0} + \sum_{J=1}^{n}(C_{ILJ} * X_J)$$

$$(S_{IL})^2 = [C_{IL0} + \sum_{J=1}^{n}(C_{ILJ} * X_J)]^2$$

$$S_I = C_I + \sum_{L=1}^{Lmax}(S_{IL})^2$$

$S_K = min(S_I)$ for I=1 to m

K = one's complement of group number code, $M - I$

where: I = 1 to m is the number of analysis categories

L = 1 to Lmax is the number of transform variable sets per I

J = 1 to n is the number of spectral dimensions per pixel

$X_J$ is the amplitude of the spectral signature along J

$C_I$ and $C_{IJL}$ are transform coefficients

### 2.1.2 Software Support

Software is available to support the MCP for its two main capabilities, categorization and intermediate product generation. Each main Fortran program calls its own macro driver, which moves data to and from the MCP using the DR11C interface device. The current software fully utilizes the 256-group, 16-variable categorization capability of the MCP. The intermediate products or linear combinations software creates an output file with the same number of bands as the input file, with the intermediate product value for each spectral dimension of each pixel in the respective band of the output file.

A partial list of the applications that are currently supported with software generation of transform coefficients is given below:

- Landsat MSS
- Landsat Thematic Mapper
- SPOT
- Aerial photography
- Spectral feature generation

## 2.2 Commercially Available Systems Similar to the MCP

The MCP has no commercially available hardware competition. There are software maximum likelihood classifiers being used on small images with few spectral dimensions, but the very low throughput of the software versions make them very inefficient for use with satellite imagery.

### 2.2.1 Array Processors

The MCP algorithm runs much more quickly on an array processor than on a mainframe computer. ERIM has a Numerix array processor version of the MCP. The speed comparison is as follows:

Test condition: 256 by 256 image with eight overlays, eight transform variables, and twenty-two groups

*Table 1. MCP Speed Comparisons*

| Version | Elapsed Time | CPU Time (VAX) |
|---|---|---|
| Software MCP | 04:27.47 | 01:57.25 |
| Numerix MCP | 02:22.00 | 00:09.61 |
| Hardware MCP | 00:37.64 | 00:14.65 |

## 2.3 Potential Applications

The MCP has potential applications in smaller image processing systems, such as ERDAS and Gould systems, and in the medical field.

### 2.3.1 Self-contained Image Processing Systems

ERDAS and Gould have shown interest in the MCP as a plug-in module for their systems. The MCP could be upgraded to use a PC bus, a VMEbus, and any other applicable buses. The additional design effort should not be extensive for the options, and it could be done in stages. First, the MCP could be in a rack of its own connected to the other system, and a later update might be to make it a plug-in board.

### 2.3.2 Applications in the Medical Field

The MCP has already been used for some research activities in the medical field. Betty Marshall used it to categorize areas in a MR (magnetic resonance) image of the brain, looking for ways to differentiate tumors. There is also interest in using the MCP to detect percent changes, invisible to the human eye, in various types of skin rashes, so that a doctor can tell quickly if a treatment is working, without wasting the patient's time and money. These applications should be pursued because there is some funding available, through NIH and others, for research.

## 2.4 Desirable MCP Enhancements

Various enhancements could be made to the current MCP design to make it more marketable. They include increasing the speed of the main processing loop, shrinking the physical size of the board using programmable logic devices (PLD,s), software development of the intermediate products capability, and interfacing to other systems.

### 2.4.1 Increased Speed

The MCP currently uses a 10MHz clock rate. A preliminary investigation into increasing the speed of the MCP was done during the last design upgrade, and the additional design effort to increase the clock rate to 20MHz should be minimal. There are also safety delays built into the design that are no longer necessary because of CMOS access times.

### 2.4.2 Decreased Size

To decrease the cost of production and increase the ease of interfacing the MCP with other devices, such as PC's, SUN's, and the Cyto-HSS, much of the discrete logic currently used in the MCP design could be replaced with programmable logic devices (PLD)'s. The design could also be checked for redundant or unnecessary logic.

### 2.4.3 Further Software Development

There is currently software to utilize the intermediate products capability of the MCP, but it is not user-friendly and it is not currently available to potential users at ERIM (IPF, etc). It was developed only to demonstrate the correct operation of the hardware. This software could be improved at minimal cost to ERIM.

### 2.4.4 Development of Interfaces to other Systems

The MCP is currently a DEC-Unibus device using a DR11C interface. Because the MCP is small in size (one board), a desirable enhancement would be interfaces to PC's, SUN's, and the Cyto-HSS. The PC-based image processing company ERDAS has already shown interest in the MCP as a plug-in device to add to its systems. These new connections would make the MCP marketable to many different companies.

### 2.5 Follow-on Activity

The MCP could have a great deal of commercial value for ERIM because of its position as a hardware device without competition. Potential customers include other processors of satellite imagery, various medical researchers and practitioners, and PC-based image processing vendors, such as ERDAS. With an increased marketing effort, the MCP could be a profitable hardware design to manufacture or license.